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ABSTRACT

The relative participation of high ability male and female college students as natural science majors and attrition of these students from the sciences to other majors were studied at a highly selective, comprehensive research university. Of concern were the following major fields: biology, microbiology, biophysics, premedicine, astronomy, chemistry, geology, geophysics, physics, and math. The effects of math aptitude and precollege science achievement on selection of the major were assessed, based on scores for the Scholastic Aptitude Test, College Entrance Examination Board Advanced Placement test, and Educational Testing Service achievement tests. Gender differences in precollege intentions to major in a natural science appear to be largely based on relative differences in high school science preparation. Well-prepared females were as likely to intend to major in the natural sciences as comparable men but females had lower overall levels of preparation. Attrition of science majors appears similar for the best prepared men and women. Less-well-prepared women, however, were more likely to abandon natural science majors than were comparable men. (SW)

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SELECTION OF UNDERGRADUATE MAJORS BY HIGH ABILITY STUDENTS: SEX DIFFERENCES AND THE ATTRITION OF SCIENCE MAJORS

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SELECTION OF UNDERGRADUATE MAJORS BY HIGH ABILITY STUDENTS: SEX DIFFERENCES AND THE ATTRITION OF SCIENCE MAJORS

ABSTRACT

With national attention once again turning to science education this study considers the relative participation of high ability male and female college students as natural science majors. The study was conducted using student records from a highly selective comprehensive research university. Gender differences in pre-college intentions to major in a natural science appear to be largely based on relative differences in high school preparation for the sciences. Well prepared females were as likely to intend to major in the natural sciences as comparable men but females had lower overall levels of preparation. Attrition of science majors appears similar for the best prepared men and women. Less well prepared women, however, were more likely to abandon natural science majors than were comparable men. In general, it appears that enhanced high school preparation is the key to increasing female participation in the natural sciences.

SELECTION OF UNDERGRADUATE MAJORS BY HIGH ABILITY STUDENTS: SEX DIFFERENCES AND THE ATTRITION OF SCIENCE MAJORS

As in the Sputnik era, concern for the number of students participating in science education in college again looms as a national concern. One response in that era was to motivate and train more students to enter careers in science. At the time, most women were neither inclined nor encouraged to major in the natural sciences but since two of three college students were men the pool of prospective science students was ample. Today the number of undergraduate women in college equals men and while there has been a marked increase in women entering traditionally male fields (Lyson, 1981) there still seems to be a large sex difference in science.

Women have been observed to be not only less likely than men to enter college intending to major in a natural science but if they do they are more likely to switch to a non-science field (Ware, 1985). If so, it means that in institutions which have seen dramatic increases in the ratio of women in the student body, combined with the lower participation rates of women in the natural sciences, the effective size of the pool of potential science majors has decreased.

This study compares the inclinations of high-ability male and female undergraduates majors to major in the natural sciences when they enter college and the relative attrition of these students from the sciences to other fields while in college. In particular, it focuses on how pre-college academic characteristics of men and women are related to the self-selection and attrition of natural science majors.

Selection of an Undergraduate Natural Science Major

A number of student and institutional characteristics affect the dynamics of selecting a science major. Of student characteristics, sex persists as the most visible correlate of who selects a natural science major (Dunteman, 1979). Other pre-college characteristics such as expressed interest in science and preparation for college work, and the academic experience of students once they enroll affect the major decision (Babu, 1985; DeBoer, 1984). Institutional factors include the sex ratio of the student body and faculty, pedagogical practices (Berkheimer, 1984) and curriculum practices (Rudd, 1984).

Pre-college interest in science appears to be a crucial, almost necessary, condition to becoming a science major. The highly structured and cumulative nature of the typical science curriculum obliges even ambivalent potential science majors to take a 'science track' from their first semester at college. Within a liberal arts curriculum which exposes students to and nurtures interest in new areas, science departments typically stand only to lose rather than gain prospective majors. Not only may students discover a subject such as linguistics, sociology or philosophy during the first two years of college, but the usual few prerequisites and unstructured curriculum of such fields makes it possible to enter them at the beginning of the junior year. In contrast, if a student slacks off the normal science track during the first two years, he or she is virtually lost as a natural science major.

Lower inclination of women to pursue the natural sciences and their greater attrition rates can be seen as part of the general problem of understanding behavior according to sex roles. Traditional cultural notions point to the presumed lack of interest or aptitude of women in the sciences based on either cultural or genetic factors. Others point to the lack of female role models on science faculties (Levine, 1984) or outright harassment by male faculty (McCormack, 1985). More promising may be to consider women's decisions about their undergraduate major as rational choices based on the structure of opportunity they perceive (c.f., Kanter, 1977) and their relative aptitude and success in studying science in high school.

METHOD OF RESEARCH AND ANALYSIS

The study is based on analysis of student academic records of a highly selective liberal arts college located in the eastern United States, with one of the most academically qualified student bodies in the country. Since natural science majors on average have higher math SAT scores than students majoring in the humanities or social sciences, use of a highly selective college has the advantage of providing a large pool of male and female students for whom scholastic aptitude is not problematic. Registrar records from two entire cohorts, one which entered college in 1980 (class of 1984) and one which entered in 1984 (class of 1988) were used for the analysis.

The study focuses on students who enter college with declared expectations of majoring in a natural science. Potential natural science majors were considered to be students who indicated interest in majoring in either the life sciences (biology, micro-biology and biophysics, and pre-meds), physical sciences (astronomy, chemistry, geology and geophysics, and physics), math or "science". While female participation in computer science and engineering is also problematic, these fields were not included so as to limit the scope of the study. Both of these fields appear to have more severe problems with respect to the integration of women and need to be considered in a separate study. Also not included are the relatively small groups of students who switched to natural science from another field (0.8% of all students did so) and the 19% of all students who began college with no specific intended major (of whom 18% became natural science majors).

General aptitude for study in the natural sciences is assumed to be indicated by a student's math SAT score, available for nearly all students in the study. Pre-college confidence and preparation in the sciences is assumed to be measured by whether or not students submitted achievement and/or advanced placement test scores in math and science. Such standardized test scores have correlations of about .5 with grades in introductory math and physical science courses at the college. While such a correlation may seem modest, the actual grade distribution it represents can be ruthless to students with lower scores. For example, in a recent basic introductory chemistry course for natural science majors, while 15% of the students in the class had math SAT's below 650, none received an A and they had an average grade of C-. In contrast, 28% of the students in the class had math SAT's of 750 and half of them received an A.

Students are required to submit at least three ETS achievement test scores as part of the admissions requirements. As well, many students take and submit scores from CEEB Advanced Placement exams in order to qualify for either course credits, to satisfy lower level prerequisites or the college's general distributional requirements.

PRE-COLLEGE ANTICIPATION OF BEING A NATURAL SCIENCE MAJOR

Admissions applications of selective colleges typically ask students to identify their anticipated major. For the college studied, 81% of entering Freshmen indicated a specific major with the rest unsure. A natural science major was selected by 25% of those who indicated some major and 21% of all students. This is somewhat higher than the national averages for private four-year colleges. Sex differences are not dramatic at this point with 24% of male applicants indicating a natural science major compared to 21% of females. Men and women are at about par for both the life sciences and mathematics at the time of application. The greatest differences lie in the physical sciences which men are men almost twice as likely to select (see Table 1) and in engineering and computer science. Women virtually matched men in the percentage who expected to major in math. The gap appears much large if engineering and computer science are included since only 3.2% of the women expected to major in these compared to 8.6% of the men.

Table 1

Pre-College Interest in Major by Sex

	Female	Male	Total
Undecided	19.7%	16.7%	18.9%
Humanities & Soc Sci	55.0	48.5	51.9
Engineering & Cpt Sci	3.2	8.6	6.3
Natural Sciences	22.1	26.2	23.9
	100.0	100.0	100.0
Natural Sciences (% of all)			
Life Sciences	13.0	11.6	12.2
Physical Sciences	5.6	11.0	8.1
Math	3.4	3.6	3.6
Total	22.1	26.2	23.9

Effect of Math Aptitude on Selection of Major

Most students at the college studied have math and verbal SAT scores in the 600-700 range, with 19.5% of all students having math SAT scores of 750 and above. As.is the case nationally, more males have very high math SAT scores than women, with 26% of the men versus 11% of the women having scores above 750 (see Table 2). While there are more males with extremely high math SAT scores, since about half the student body is female there is no lack of high aptitude women for whom the decision about whether to pursue a science major clearly does not hinge on math aptitude. Not only do many women students have strong math aptitude, as measured by the SAT test, but many of them also had success in the study of science based on their performance on CEEB advanced placement examinations and ETS achievement tests (see Table 3).

Table 2

Distribution of Math SAT Scores
by Area of Expected Undergraduate Major

		Natural Science Group			Non-Science	Total
		Life	Math	Physical		
Females	<55	8.5%	0.0%	1.8%	10.9%	8.4%
	55-59	5.4	0.0	9.1	10.4	9.2
	60-64	23.3	3.2	16.4	29.4	25.5
	65-69	17.8	12.9	10.9	20.3	19.7
	70-74	31.8	51.6	32.7	22.4	26.5
	75-80	13.2	32.3	29.1	6.6	10.6
						100.0%
Males	<55	5.3%	0.0%	0.7%	5.1%	3.7%
	55-59	2.6	0.0	2.7	6.9	5.0
	60-64	20.4	0.0	2.7	19.1	15.6
	65-69	15.8	6.2	17.4	19.1	17.3
	70-74	28.9	29.2	32.2	32.5	32.2
	75-80	27.0	64.6	44.3	17.3	26.2
						100.0%

Men and women throughout the math SAT range are about as likely to select the life sciences as a possible area of study, but math and physical science tend to be selected by students with higher scores. Students in the highest math SAT ranges (above 750) were more than twice as likely to expect to major in a natural science field as were students in the lower SAT ranges (400-600) and ten times as likely to major in physical science. Men and women show surprisingly similar patterns for those who anticipated being math majors. While women in the highest and lowest SAT ranges are

about as likely to pick the physical sciences as the men, those from 650-750 were less likely to do so but slightly more likely to pick a life science major.

Table 3

College Entrance Test Scores
by Pre-College Interest in
Natural Science Major and Sex

Anticipated area of undergraduate major	Average SAT Scores: Verbal F	Verbal M	Math F	Math M	% Students with high test scores: CEEB AP Scr of 5 F	CEEB AP Scr of 5 M	Achv Tst Scr>700 F	Achv Tst Scr>700 M
Undecided	66.9	65.4	66.6	69.6	16%	30%	19%	23%
Humanities & Soc Science	66.9	65.6	64.5	68.1	10	18	9	14
Engineering & Cpt Sci	61.8	62.2	65.4	71.2	11	40	15	33
Life Sciences	64.3	64.1	67.9	69.1	17	36	18	34
Physical Sciences	65.0	66.4	69.8	72.8	34	58	39	38
Math	66.7	66.4	72.6	76.0	39	77	32	39

Given the relationship between SAT scores and selection of majors, to what extent do differences in the distribution of math aptitude scores explain the disparity in interest in physical science between men and women? As noted earlier, fewer women are in the upper ranges of math SAT scores, the very regions where aptitude appears to have an affect in leading to a science major. The higher likelihood of students with upper range math SAT scores expecting to have a science major accounts for some of the difference between men and women (see Table 4). For each of the sub-fields, the women's rate of expected participation was recalculated by standardizing it the male distribution of math SAT scores. For example, if high school women still selected math as a likely major at the female rate by SAT score but had the same distribution of math SAT scores as men, then the female rate for choosing math potential major would increase from 3.4% to 4.9%, higher than the actual male rate of 3.6%.

Table 4

Students Anticipating Natural Science Majors
by Sex and Math SAT Scores

	Natural Sciences		Life Sciences		Physical Sciences		Math	
	F	M	F	M	F	M	F	M
75-80	42%	41%	17%	12%	16%	19%	10%	9%
70-74	29	25	16	11	7	12	6	3
65-69	17	24	12	11	3	12	2	1
60-64	16	17	12	15	4	2	0	0
55-59	13	12	8	6	6	6	0	0
<55	15	19	13	17	1	2	0	0
All students	22.1	26.2	13.0	11.5	5.6	11	3.4	3.6
Female rate % Standardized to male SAT's	30%		19.5%		7.7%		4.9%	

Effect of Pre-College Science Achievement

Strong high school preparation in the sciences also increases the chances that students will anticipate a natural science major. Submission of CEEB advanced placement or ETS achievement tests in math and science to a college admissions office is good evidence of a student's relative pre-college confidence and accomplishment in science.

Further similarity in the effect of test scores on major selection can be seen in Table 5 which shows the relative anticipation of males and females of a science major by their standing on various CEEB advanced placement tests and ETS achievement test scores. Perhaps the most notable difference in the pattern by sex is that high biology scores lead only 33% of the women to see themselves as a science major compared to 52% of the men. Otherwise, women who have similar scores to men appear only slightly less likely to anticipate a natural science major.

Table 5

Anticipation of Male and Female Students
of Natural Science Major by
Pre-College Science and Math Aptitude and Achievement
(cell entries are percentages)

	Science and Math CEEB Advanced Placement Scores of Five					
	0		1		2+	
Math SAT	F	M	F	M	F	M
750-800	32%*	36%	51%	42%	62%	48%
700-740	28	21	34	34	33	48
650-690	19	23	20	33		
600-640	16	16	21	40		
<600	14	15				

*Cell contents are the percentage of students in that cell (cells are collapsed if there are less than ten students) cell) who indicated they would be a science major on their admissions application - e.g., 32% of women with math SAT scores of 750 to 800 and no CEEB tests with scores of five said they expected to major in a natural science.

The most dramatic difference between men and women lies in the number who participate in the physical science advanced placement tests compared to men. Even here, however, some of these differences dwindle if the women's rate is standardized to the men's math SAT distribution. For example, Table 6 shows that although only 5.6% of the women students took the Chemistry Advanced Placement exam compared to 10.1% of the men, the women's rate standardized to the men's math SAT score distribution increases to 9.2%. Likewise the percentage of women who took the Math BC Advanced Placement exam jumps from the actual 10.1% to standardized rate of 16.1% compared to 18.1% of the men who took the Math BC exam. The same technique fails to account for the differences in the number of students who took the two physics exams, although so few students overall took these exams that if just a few more women did so it would change the percentage picture sharply. Only 0.5% of the women took a physics exam compared to 5% of the men.

Table 6

Anticipation of Male and Female Students
of Natural Science Major by
Pre-College Science and Math CEEB Advanced Placement Exams
(cell entries are percentages)

		Percentage Expecting to Major in Natural Sciences by CEEB Adv Placement Test Scores				All students		Students expecting nat science major	
CEEB AP		None	1-3	4	5	Took Exam	Avg Scr	Took Exam	Avg Scr
Biology	F	23%	36%	38%	33%	10.8%		15.0%	
	M	31	28	29	52	11.1		15.0	
Chemistry	F	23	23	50	58	5.1		11.5	
	M	31	29	47	60	9.6		14.0	
Physics C (Elect)	F	24	(0/1)	(0/1)	(3/3)	0.5		1.5	
	M	31	60	43	55	4.4		7.2	
Physics C (Mech)	F	24	(0/1)	(1/1)	(4/4)	0.6		1.5	
	M	31	53	57	54	5.6		9.3	
Math AB	F	22	36	43	52	15.3		22.6	
	M	29	27	40	58	19.1		24.2	
Math BC	F	22	35	28	46	9.9		19.1	
	M	30	30	39	50	17.7		25.0	
Engl Lit	F	24	33	29	25	24.3		26.7	
	M	33	38	27	25	20.5		19.6	

Albeit that there were proportionally fewer of them, women who demonstrated high math aptitude and pre-college science achievement selected natural science majors at about the same rate as comparably prepared men, and in the case of math and life science at higher rates. They also presented about the same number of advanced placement scores as men of comparable math SAT scores. This strongly suggests that the absolute differences so often observed between male and female students in their inclination and preparation to pursue natural science majors are largely rooted in the dissimilar distribution of male and female math SAT scores. Over one and a half times as many men had math SAT scores in the range above 750, which produces markedly higher yields of well prepared students as prospective physical science majors.

Residual differences unaccounted for by math SAT scores in the inclination of women to anticipate a physical science major appears to lie in the weaker pre-college preparation of women in the math SAT ranges of 650-750 in physics in high school. Note that the handful of women who scored 5 on the physics advanced placement exam all had a natural science major.

ATTRITION OF NATURAL SCIENCE MAJORS AFTER ENROLLMENT

The survival rates of students starting out as natural science majors are shown in Tables 7 and 8. Nearly all of the students (94%) who indicated they expected to major in the natural sciences actually began to take required science courses in their first semester. Only 3% of the women failed to do so compared to 8% of the men. This suggests that student claims of interest in natural science on college admissions applications can be taken fairly seriously, if not the specific field selected. Conversely, students who designate the humanities are unlikely to major in a natural science major as only 4% of prospective humanities and social science majors switched to a natural science. Only 13% of students who enter as engineering or computer science students switched to the natural sciences.

Course selection patterns of actual natural science majors were analyzed to determine the modal pattern for the science track which is to take two or three required science and math courses in each of the first four semesters. Of students who graduated with a life or physical science major, only 4% did not begin on a science track from the first term.

Ultimately, 45% of the women who started out as natural science majors actually did so, compared to 55% of the men. Relatively few students withdrew from school or were dismissed - attrition primarily occurred from students switching to other fields. Differential survival rates of students who started out as natural science majors and who did declare a natural science major are shown in Table 8 by SAT scores and advanced placement tests. In general, attrition appears to be related to pre-college preparation - the better prepared the student on entry the more likely his or her survival. For example, while only 21% of women with the highest math SAT scores but no scores of five on CEEB science tests actually became a natural science major, 51% of those who had two scores of five did. Students who attempt to major in the natural sciences without benefit of advanced placement credits appear to be at a significant disadvantage. Even at the highest levels, aptitude does not appear to be able to make up for lack of pre-college preparation. Overall, the picture for women shows that their attrition rate, when controlling for aptitude and achievement tests, slightly exceeds that of males with a similar general pattern.

Earlier it was noted that men and women of comparable aptitude and achievement were near equally likely to intend to major in a natural science, if not the physical sciences. What is the picture after they have finished four semesters? It turns out that women of comparable aptitude and pre-college achievement also have similar survival rates as the men.

Table 7

Actual Rate of Natural Science Majors
for Students Anticipating Nat Sci Major
When Entering College by Pre-College Tests

	Science and Math CEEB AP Exams with Score of 5 + ETS Achv Tests with Score over 750					
	0		1		2+	
Math SAT	F	M	F	M	F	M
750-800	21%*	40%	43%	63%	51%	59%
700-740	33	39	30	56	66	61
650-690	33	35	35	6		
600-640	19	33	33	33		
<600	31	18				

Table 8

Actual Rate of Natural Science Majors
for All Students by Pre-College Tests

	Science and Math CEEB AP Exams with Score of 5 + ETS Achv Tests with Score over 750					
	0		1		2+	
Math SAT	F	M	F	M	F	M
750-800	3%	14%	10%	23%	43%	37%
700-740	17	9	17	22	25	27
650-690	11	11	6	11		
600-640	6	11	8	22		
<600	6	5				

*Cell contents are the percentage of students in that cell (cells are collapsed if there are less than ten students) cell) who indicated they would be a science major on their admissions application - e.g., 21% of women with math SAT scores of 750 to 800 and no CEEB tests with scores of five said they expected to major in a natural science.

IMPLICATIONS OF FINDINGS

This study was initiated to probe for correlates of the lower participation and greater attrition rates of women as undergraduate majors in the natural sciences with the assumption that women were significantly underrepresented. It was not expected to find there are basically similar patterns in major selection and attrition between men and women when controlling for aptitude and pre-college achievement.. The findings suggest that women for the most part behave like comparable men in seeking a natural science major. Much of the persistent difference in outcomes within the high-ability group of students studied appears to be largely explained by the relative distributions of men and women at the higher ranges of math aptitude, where students are much more likely to pursue study of the physical sciences. This is at variance with explanations such as the tenacity of sex roles or the lack of role models to explain the gap.

The findings also suggest that there are effective limits on how much the number of science majors can be increased without changing the sex ratios of the student body, an unlikely alternative for any school. Despite superior preparation for work in the natural sciences, it appears that about 40% of the very best prepared students, male or female, will opt for primary study in other fields. Often, of course, these students are also well prepared and interested in other areas.

Clearly more analysis of the process of attrition of science majors needs to be conducted in other settings, in order to understand the role of high school preparation in becoming a natural science major. It may be that the extensive use of advanced placement credits in meeting science requirements by high-ability students makes it very difficult for students not so well prepared to compete.

The unexpected nature of this finding suggests that it be greeted with caution. It could be a pattern peculiar to colleges with relatively large numbers of students in the upper ranges of the math SAT's. Though there has been near convergence between men and women in study of the life sciences, there is a still a gap in their participation in chemistry, physics, and math. Attrition rates must be further analyzed to detect earlier, there are also serious differences in computer science and engineering which need to be investigated.

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